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FACE DETECTION AND RECOGNITION USING O-LINE EDGE MAPS (O-LEM)

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ABSTRACT

Face detection has advanced dramatically over the past three decades. Algorithms can now quite reliably detect faces in clutter in or near real time. However, much still needs to be done to provide an accurate and detailed description of external and internal features. This paper presents an approach to achieve this goal.Previous learning algorithms have had limited success on this task because the shape and texture of facial features varies widely under changing expression, pose and illumination. We address this problem with the use of Histogram Equalization (to make the intensity even across the face), Phong Shading (to illuminate the face to be recognized for better and efficient results), and Fast Fourier Transform (to eliminate the broken lines that are formed after using Line Edge Mao Algorithm). We then combine this approach with Mahalanobis Distance Vector Algorithm and Line Edge Map Algorithm to provide an accurate and detailed detection of the shape of the major facial features (brows, eyes, nose, mouth and chin). A performance evaluation has been done and experimental results demonstrate the method to be almost as precise as manual detection, ~1% error.

KEYWORDS: Line Edge Mapping, Phong Shading, Fast Fourier Transform, Mahalanobis Distance Vector

1. INTRODUCTION

Face detection and recognition are challenging tasks due to variation in illumination, variability in scale, location, orientation (up-right, rotated) and pose (frontal, profile). Facial expression, occlusion and lighting conditions also change the overall appearance of face. Face detection and recognition has many real world applications, like human/ computer interface, surveillance, authentication and video indexing.The proponents of large-scale face recognition feel that it is a necessary evil to make our country safer. It could benefit the visually impaired and allow them to interact more easily with the environment. Also, a computer vision-based authentication system could be put in place to allow computer access or access to a specific room using face recognition. Another possible application would be to integrate this technology into an artificial intelligence system for more realistic interaction with humans.

We talk of face (and facial feature) detection, rather than shape modeling, because the algorithms developed herein corresponding to this category. The algorithm is based on the generic training of classifiers robust to shape and texture variations due to expression, pose and illumination changes.In this paper we are using the Line Edge Map based approach using Mahalanobis distance. Mahalanobis distance is used to find outliers in a set of data. It provides a way to measure how similar some set of conditions is to a known set of conditions. It accounts the covariance among variables. Another technique used in this paper is illumination of face image using Phong reflection model, Histogram Equalization and to remove the various discrepancies from the image, we have used Fast Fourier Transform (FFT). The results and the algorithm have been optimized to give better results. The proposed algorithm is called **O**(Optimized)**-Line Edge Mapping Algorithm (O-LEM).**

This paper is structured as follows: Section 2 throws light on the details of various face detection and recognition techniques proposed in earlier papers. Section 3 provides an insight to the details of the face detection and recognition technique proposed in this paper using Phong Reflection Model, Mahalanobis distance and Fast Fourier Transform. Section 4 describes the details of how new features are integrated and executed in the paper. Section 5 ends the paper with a conclusion.

2. RELATED WORK

Many methods have been proposed to resolve the problems. For example, the template-matching methods [1], [2] are used for face localization and detection by computing the correlation of an input image to a standard face pattern. The feature invariant approaches are used for feature detection [3], [4] of eyes, mouth, ears, nose, etc. The appearance-based methods are used for face detection [5], [6], [7], neural network [8], [9], and information theoretical approach [10], [11]. Nevertheless, implementing the methods altogether is still a great challenge. Fortunately, the images used in this project have some degree of uniformity thus the detection algorithm can be simpler: first, the all the faces are vertical and have frontal view; second, they are under almost the same illuminate condition. This project presents a face detection technique mainly based on the color segmentation, image segmentation and template matching methods. For facial feature extraction, there have been a number of methods developed and introduced for this purpose. Modeling is the typical relative brightness between the regions, the ratio template outlines constrains for a region to be considered to contain a face. Typically, irrespective of the illumination conditions, the eyes are darker than the nose. There are many algorithms for edge detection.

Three of which are: gradient, Laplacian algorithm and canny algorithm [12]. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image while the Laplacian method searches for zero crossings in the second derivative of the image to find edges.

The canny algorithm uses maximum and minimum threshold in finding the segments of the strong edges. A variety of approaches have been suggested for segmenting the human face from images [12] [13]. Kanade [13] used projection analysis on a binary image obtained by a Laplacian operator to gray scale images. Brunelli et al. [16] uses the projection analysis by performing vertical and horizontal edge detection. They also discussed the segmentation of human face using the geometrical features. Geometric feature based segmentation and matching involves decomposing the face image into pertinent features like eyes, nose, mouth, chin and their spatial relationship to one another using Gabor wavelet decompositions [15]. In template matching approach [14], the construction of an artificial template is used to match with the prominent features of the face. V. Govindaraju et al. [19] attempted to locate the face in an image using a mode template constructed from a hair curve and face side curves. They used a cost function approach to group together prospective left and right face side curves having an appropriate displacement and angular orientation. Another approach different from template matching is used by Turk et al [21]. In their approach, faces are projected on to a feature space called the face space defined by eigen-faces and are determined by the set of eigenvectors. Sirohey [22] used an ellipse to represent the head region in edge map. Sangho [12] used a partial ellipse to fit the head counter. Thus, it is observed to have the face region distinguished from the background clutter. On the other hand, to segment the face region from cluttered images Hough [13] based techniques are also used. The Elliptical Hough Transform [14] deals with finding elliptical objects from edge images. Geometrical symmetry properties are also used along with HT to identify the elliptical objects [15] [16]. But HT based methods takes large memory for Hough space and leads to more computational

complexity. Some interesting properties of statistical parameters such as small and large eigenvalues of covariance matrix is used to identify the corners and linear features [17] [18] [19]. The same properties are also used to detect circular and elliptical objects [20].

3. PROPOSED FRAMEWORK

In this paper, I have taken different measures to improve upon the existing techniques of face detection and recognition algorithm. I have introduced a new way of illuminating the facial region and provided a means of determining the resemblance of one point set to another which was never used before in face detection and recognition algorithms. I have modified the existing technique by using better methods and techniques. Figure 1 shows the proposed algorithm and its framework.

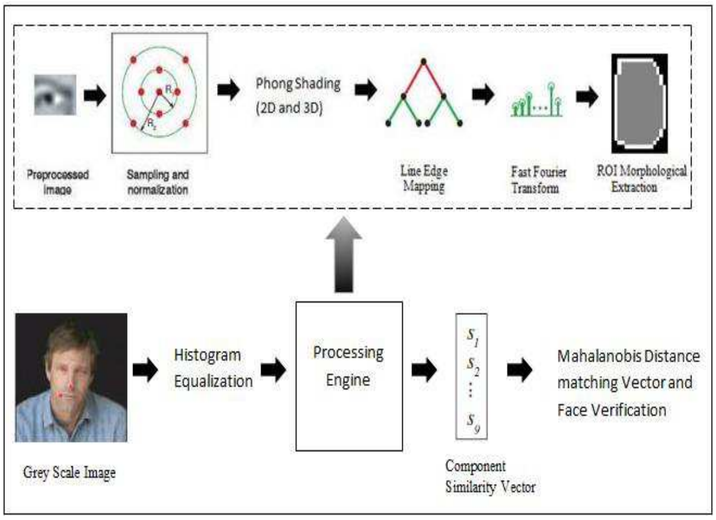

Figure 1: The Proposed Face Detection System

3.1 Histogram Equalization

Histogram equalization is a technique of improving the global contrast of an image by adjusting the intensity distribution on a histogram. This allows areas of lower local contrast to gain a higher contrast without affecting the global contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The original histogram of a face has the bimodal type, the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced. [20]

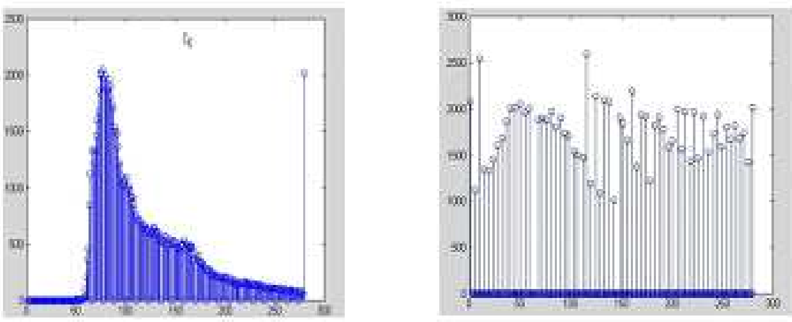

Figure 2: (a) Original Histogram of Face, (b) Histogram after Equalization Enhancement

The results of histogram equalization are as below:

Figure 3: (a) Original Image (b) Enhanced Image after Histogram Equalization

3.2 Sampling and Normalization

A locally adaptive Binarization method is performed to binarize the face.In this method image is divided into blocks of 16 x 16 pixels. A pixel value is then set to 1 if its value is larger than the mean intensity value of the current block to which the pixel belongs. [20]

3.3 Phong Shading (2D and 3D)

We have used the technique of Phong Reflection as a way of illuminating the faces. In this model, we think of the interaction between light and a surface as having three distinct components:

The *ambient* component is usually given a dim constant value, such as 0.2. It approximates light coming from a surface due to all the non-directional ambient light that is in the environment. In general, you'll want this to be some tinted color, rather than just gray. $[r_a,g_a,b_a]$. For example, a slightly greenish object might have an ambient color of [0.1, 0.3, 0.1]. [20]

The *diffuse* component is that dot product n•L that we discussed in class. It approximates light, originally from light source L, reflecting from a surface which is diffuse, or non-glossy. One example of a non-glossy surface is paper. In general, you'll also want this to have a non-gray color value, so this term would in general be a color defined as: $[r_d,g_d,b_d](n\bullet L)$. [20]

Finally, the Phong model has a provision for a highlight, or *specular* component, which reflects light in a shiny way. This is defined by $[r_s,g_s,b_s](R\bullet L)^p$, where R is the mirror reflection direction vector we discussed in class (and also used for ray tracing), and where *p* is a specular power. The higher the value of *p*, the shinier is the surface. [20]

The complete Phong shading model for a single light source is:

$$[r_a,g_a,b_a]+[r_d,g_d,b_d]\max_0(n\bullet L)+[r_s,g_s,b_s]\max_0(R\bullet L)^p$$

If you have multiple light sources, the effect of each light source L_i will geometrically depend on the normal, and therefore on the diffuse and specular components, but not on the ambient component. Also, each light might have its own [r,g,b] color. So the complete Phong model for multiple light sources is:

$$[r_a,g_a,b_a]+ \Sigma_i([L_r,L_g,L_b]([r_d,g_d,b_d]\max_0(n\bullet L_i) +[r_s,g_s,b_s]\max_0(R\bullet L_i)^p))$$

This technique has an edge over the other face illumination techniques as it describes the way a surface reflects light as a combination of the diffuse reflection of rough surfaces with the specular reflection of shiny surfaces. The reflection model also includes an *ambient* term to account for the small amount of light that is scattered about the entire scene. [21]

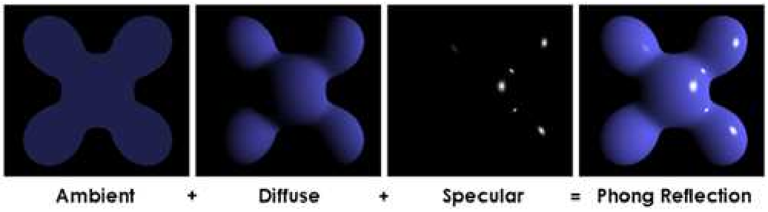

Figure 4: Working of Phong Shading Model [21]

3.4 Line Edge Mapping

This algorithm describes a new technique based on line edge maps(LEM) to accomplish face recognition. In addition, it proposes a linematching technique to make this task possible. In opposition with otheralgorithms, LEM uses physiologic features from human faces to solve the problem; it mainly uses mouth, nose and eyes as the most characteristic ones.

In order to measure the similarity of human faces the face images are firstly converted into gray-level pictures. The images are encoded intobinary edge maps using Sobel edge detection algorithm. This system isvery similar to the way human beings perceive other people faces as it wasstated in many psychological studies. The main advantage of line edgemaps is the low sensitiveness to illumination changes, because it is anintermediate-level image representation derived from low-level edge maprepresentation.[3] The algorithm has another important improvement, it is thelow memory requirements because the kind of data used. In Figure 5, there is an example of a face line edge map; it can be noticed that it keeps facefeatures but in a very simplified level.

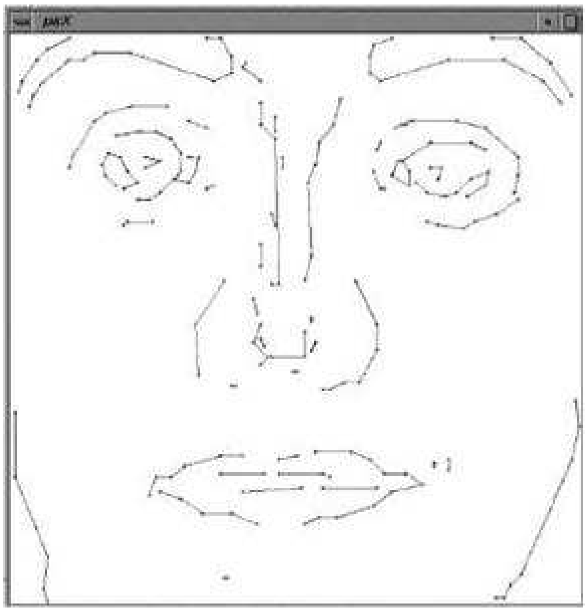

Figure 5: Example of Face Line Edge Mapping

3.5 Fast Fourier Transform

In this paper, a feature extraction method based on the fast Fourier transform (FFT) is proposed for the use of face detection. In this method we divide the image into small processing blocks (32 x 32 pixels) and perform the Fourier transform according to equation:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \tag{1}$$

For u = 0, 1, 2, …. 31 and v = 0, 1, 2, ..., 31.

In order to enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original FFT = abs (F (u, v)) = |F (u, v)|.

So we get the enhanced block according to the equation:

$$g(x,y) = F^{-1}\{F(u,v) \times |F(u,v)|^{k}\} \tag{2}$$

where F^{-1}(F (u, v)) is given by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \tag{3}$$

For x = 0, 1, 2 …31 and y = 0, 1, 2 ...31.

The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. A high value of k improves the appearance of the ridges by filling up small holes in ridges, but too high value of k can result in false joining of ridges which might lead to a termination become a bifurcation.

The Advantage of this Approach is the enhanced image after FFT has improvements as some falsely broken points get connected and some spurious connections get removed. Another advantage is that it does not require the computation of intrinsic images for its operation. This has the effect of increasing the dominant spectral components while attenuating the weak components. However, in order to preserve the phase, the enhancement also retains the original spectrum F(u,v). [22]

3.6 ROI Morphological Extraction

ROI extraction is done using two Morphological operations called OPEN and CLOSE. The OPEN operation can expand images and remove peaks introduced by background noise. The ‘CLOSE’ operation can shrink images and eliminate small cavities. Figure 6 shows the final ROI of the face which is the bound area after subtraction of the closed area from the opened area. Then the leftmost, rightmost, uppermost and bottommost blocks out of the bound area are discarded.

Figure 6: ROI Extraction

3.7 Mahalanobis Distance

The Mahalanobis distance is a descriptive statistic that provides a relative measure of a data point's distance (residual) from a common point. [21] The Mahalanobis distance is used to identify and gauge *similarity* of an unknown sample set to a known one. We have used it in our project as a face detection technique. **The Mahalanobis**

Distance is a better distance measure when it comes to pattern recognition problems. It takes into account the covariance between the variables and hence removes the problems related to scale and correlation that are inherent with the Euclidean Distance. It is given as:

$$d(x, y) = \sqrt{(x-y)^T C^{-1}(x-y)}$$

where C is the covariance between the variables involved.

The Mahalanobis Distance has the Following Advantages over Other Techniques, like Hausdorff Distance

- It accounts for the fact that the variances in each direction are different.
- It accounts for the covariance between variables.
- It reduces to the familiar Euclidean distance for uncorrelated variables with unit variance.

The Mahalanobis distance accounts for the variance of each variable and the covariance between variables. Geometrically, it does this by transforming the data into standardized uncorrelated data and computing the ordinary Euclidean distance for the transformed data. In this way, the Mahalanobis distance is like a univariate z-score: it provides a way to measure distances that takes into account the scale of the data.

4. EXPERIMENTAL RESULTS

Performance evaluation is the key aspect of undertaking any research work. So I have evaluated the work and finally concluded by elaborating the efficiency of the work. In the following section we show the results obtained on integrating the proposed work with the existing work and extending its capabilities to produce better results. The proposed framework shows considerable improvements in result as compared to the existing framework. By extending the framework and using better surface illumination algorithms the efficiency in face detection went up.

The experiments were performed using three different algorithms: the edge map, the Eigen faces and LEM. Therefore, tables with a comparison of the algorithms are provided.Tables with the corresponding results are shown in order to make a good comparison with the other algorithms. The results show probabilities of correct detection of the different algorithms and some experiments include variation of parameters such as number head movement or light direction.

Table 1: Results for Edge Map (EM), Eigen Face -20 (EF) and Line Edge Mapping (LEM)

	Database 1			Database 2		
Method	EM	EF	O-LEM	EM	EF	O-LEM
Recognition Rate	97%	99%	100%	88%	55%	92%

Table 2: Results for Edge Map (EM), Eigen Face- 20 (EF) and Line Edge Mapping (LEM) for Light Variations

	EM	EF	O-LEM
Left Light On	26.11%	76.28%	92.66%
Right Light On	49.11%	82.67%	84.22%
Both Lights On	64.29%	54.62%	72.98%

Table 3: Results for Edge Map (EM), Eigen Face - 20 (EF) and Line Edge Mapping (LEM) for Different Head Poses

	EM	EF	O-LEM
Looks Left/Right	50.00%	75.00%	76.09%
Looks Up	64.62%	64.29%	69.00%
Looks Down	67.67%	54.10%	70.00%

5. CONCLUSIONS

In this paper, we have extended the existing face detection and recognition technique by integrating new features, Phong reflection model, Mahalanobis Distance and Fast Fourier transform. New methods have improved the face illumination, filled the broken ridges and improved the efficiency in face comparison considerably at later stages. OLEM algorithm demonstrated a better accuracy than the Eigen faces methods with size variations. While Eigen faces difficultly achieved an acceptable accuracy, OLEM managed to obtain percentages around 90%, something very good for a face recognition algorithm. For lighting variations too the OLEM algorithm kept highlevels of correct recognitions. Experimental results have shown improvement in efficiency when new methods are integrated in the existing system. With the proposed work, the effectiveness of face detection and recognition has been studied carefully. Further investigation to the topic reveals that face recognition using Mahalanobis distance can yield good results. The concept has been worked out and can be used in future.

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